

# CALIFORNIA STATE DEPARTMENT OF PUBLIC HEALTH

WALTER M. DICKIE, M.D., Director

## Weekly Bulletin



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## *The Carbon Monoxide Hazard on California Highways*

By J. P. RUSSELL, M.D., Chief, Industrial Hygiene Service, State Department of Public Health

In a survey conducted in 1938 by the Industrial Hygiene Service, State Department of Public Health, in conjunction with the California Highway Patrol, State Department of Motor Vehicles, 1105 commercial motor vehicles of various types were tested during five-minute runs on the highway, under varying weather and road conditions, to determine the amount of carbon monoxide in the air breathed by the driver. Two per cent of these vehicles were found to be in a potentially dangerous condition, due to concentration in the driver's compartment of over 0.01 per cent of carbon monoxide, which may cause headache, sleepiness, weakness, faulty judgment, and impaired driving ability, if inhaled continuously over a period of six hours or longer. In each vehicle in which the carbon monoxide concentration was found to exceed this toxic threshold, the source of the trouble was traced to some demonstrable defect in the exhaust system, from which engine exhaust gases were escaping and entering the driver's compartment, in many cases without the driver being aware of their presence.

The great majority of vehicles included in the above-mentioned study were trucks and buses, since the drivers of such vehicles are engaged in an industrial occupation in which exposure to carbon monoxide is a potential occupational health hazard directly associated with their employment.

In order to obtain a comparable series of tests on

noncommercial motor vehicles, and to study more fully the relationship of certain relevant factors, such as length of exhaust pipe, and driving with windows open and closed, to the amount of gas entering the car, a similar survey has been made of 1005 passenger automobiles.

The instruments used in this study were the same as those employed in the commercial vehicle survey. The carbon monoxide concentration in the automobiles was determined by means of a portable M. S. A. Hopcalite Carbon Monoxide Indicator. Wind velocity and direction readings were made with an Alnor velometer. Temperature and relative humidity determinations were made with a sling psychrometer.

The four-mile section of U. S. Highway No. 70, between Blythe, California, and the plant quarantine station at the state line, was selected as the location for the survey for several reasons. Since all automobiles entering California are required to stop at this station for inspection, inconvenience to drivers and passengers, and interference with traffic, were minimized by starting the five-minute tests at this point. Also, most westbound automobiles make an uninterrupted run of 210 miles between Phoenix, Arizona, and Blythe, and most eastbound cars cover the 200 miles between Los Angeles and Blythe in one continuous traveling period. Therefore, the majority of automobiles enter-



ing Blythe from either direction have been run continuously for several hours. It is under such conditions of prolonged exposure, that the driver and passengers are most likely to experience the toxic effects of relatively low concentrations of carbon monoxide in the car. Several instances have been reported in which the occupants of an automobile reaching Blythe, after a continuous three or four hour run, have gotten out of the car, walked a short distance, and collapsed, due to partial carbon monoxide asphyxia. They had inhaled sufficient carbon monoxide from engine exhaust gases to build up a considerable carbon monoxide-haemoglobin blood saturation. As long as they were riding quietly in the car, their percentage of free haemoglobin was sufficient to meet the oxygen demand of their tissues, with no symptoms other than headache and slight nausea. When they left the car, the physical exertion of walking called for more oxygen than the partially saturated blood could supply, and loss of consciousness ensued.

Official signs were posted at the quarantine station, and four miles west of this point, at the outskirts of Blythe, to indicate the terminals of the five-minute test run. Automobiles to be tested were taken at random as they reached either of these terminals. After explaining the nature and purpose of the survey to the driver, the tester entered the car with the carbon monoxide indicator, and rode to the other end of the test run, making a continuous reading of the carbon monoxide concentration at the driver's breathing level, while the car was being driven at a normal speed. Comparative readings were taken with windows both open and closed. In case there was no room for the tester in the car, the front seat passenger was asked to transfer to the Highway Patrol car, which followed the car being tested over the four-mile run. The most cordial cooperation was obtained from drivers and passengers of all cars included in the survey.

When the concentration of carbon monoxide in the car was found to be 0.01 per cent or higher, the source of the trouble was located by checking along the entire length of the exhaust system, from engine to tail pipe, with the car at a standstill and the engine idling. Large defects, such as broken mufflers and missing tail pipes, were obvious on visual inspection. Small leaks in the exhaust line, due to loose connections and defective gaskets, and unnoticeable on casual inspection, were immediately apparent when the flexible hose attached to the carbon monoxide indicator was held at these points. All defects found were pointed out to the driver, with recommendations for necessary repairs.

The two carbon monoxide indicators used in the survey were calibrated daily, and the accuracy of their readings was insured, by making simultaneous determinations with both instruments of the carbon monoxide concentration in a Highway Patrol car converted into a gas chamber by sealing cracks and introducing engine exhaust gas with a hose.

Of the 1005 automobiles in which determinations of carbon monoxide concentration were made, 975, or 97 per cent, were found to contain less than 0.01 per cent of carbon monoxide in the air at the driver's breathing level, during five-minute test runs. Thirty cars, or 3 per cent of the total number tested, contained concentrations of the gas in excess of this maximum safe limit. Fifty per cent of these potentially dangerous cars were ten or more years old.

In a majority of cars in which comparative readings could be made with windows both open and closed, the concentration of carbon monoxide at the driver's breathing level was found to be higher when one or more windows were open than when all windows were tightly closed. This was particularly noticeable in the case of cars with tight floor coverings, and with no large openings in the dash between engine compartment and body. This illustrates the fallacy of the widespread belief that keeping windows open while driving is in itself a guarantee of protection against inhaling dangerous amounts of gas. On the contrary, if gases are escaping from a leak in the exhaust system, the suction created by driving with open windows may draw into the car larger quantities of gas than would enter with windows closed, with a correspondingly greater danger of carbon monoxide asphyxiation.

In each of the 30 automobiles in which a concentration of carbon monoxide in excess of 0.01 per cent was found, the source of the trouble was traced to one or more of the following defects in the exhaust system:

1. Blow-by, or escape of exhaust gases from the breather pipe due to faulty seal between pistons and cylinder walls, or from worn valve guides.
2. Blown-out gasket or loose connection between exhaust manifold and engine or exhaust pipe.
3. Holes in exhaust pipe.
4. Holes in muffler.
5. Leaky connection between muffler and exhaust pipe.

In the absence of exhaust system leaks, the amount of gas reaching the breathing level of driver and passengers was found to be consistently greater in the case of cars equipped with short exhaust pipes, than



in cars with long pipes, regardless of wind direction. These results were verified by making carbon monoxide readings in a highway patrol car equipped with a long exhaust pipe, during a ten-mile run which included head, tail, and cross winds, after which, first a short, and then a medium exhaust pipe was substituted for the extended pipe, and carbon monoxide determinations were made in the same car over the same course, under identical wind and road conditions.

Tests for carbon monoxide made in several new automobiles of different makes, during thirty-minute runs, over a fixed course, with head, tail, and cross winds, and with all possible combinations of front and rear windows open and closed, did not show the presence of appreciable quantities of carbon monoxide in the car. The results of these tests, made under controlled conditions, tend to substantiate the belief that drivers and passengers in cars which are free from exhaust system defects, are exposed to little, if any, danger of carbon monoxide asphyxiation on the highway, regardless of wind conditions and window adjustments.

During the survey an accident occurred near Blythe, which furnished an opportunity for immediate investigation of the circumstances involved, and which is cited as an illustration of the accident hazard due to exhaust system leaks. A 1937 sedan being driven at moderate speed, on a straight, level highway, practically free from traffic, left the road about ten miles west of Blythe, ran into the ditch, and turned over twice. One of the Highway Patrol officers of the survey party arrived at the scene of the accident a few minutes later. He noted from tire marks made by the car that the vehicle had wandered from side to side of the highway before leaving the road. A sample of the driver's blood, taken one hour after the accident, and tested by the pyrotannic acid method, showed that 18 per cent of the blood haemoglobin was combined with carbon monoxide. Since it is generally accepted that about one-half of the carbon monoxide in the blood washes out in the first hour after removal from exposure to the gas, this test indicated that at the time of the accident the driver of the car probably had a carbon monoxide-haemoglobin saturation of about 35 per cent. It has been demonstrated that this percentage of blood saturation with carbon monoxide is sufficient to cause headache, weakness, nausea, dizziness, sleepiness, faulty judgment, impaired driving ability, and in some cases unconsciousness. On questioning the driver of the wrecked car, it was learned that she had noticed a hissing sound in the engine shortly after

leaving Indio, about eighty miles west of the scene of the accident. She had paid no further attention to this noise, but had continued driving toward Blythe. She noticed a gradually increasing headache, and sleepiness, before losing consciousness. She had no recollection of events immediately prior to or following the accident. A careful inspection of the wrecked car, made on the following morning, showed that it was in perfect mechanical condition except for a blown-out exhaust gasket between the manifold and exhaust pipe and several small holes in the dash between the engine compartment and body of the car. These defects were undoubtedly responsible for the escape of engine gases from the exhaust system, and their entrance into the car in sufficient quantities to cause partial asphyxiation of the driver. All the elements in the case—physiological effects, carbon monoxide-haemoglobin blood saturation, and exhaust system defects—fit together to complete a typical picture of an accident caused by carbon monoxide inhalation.

### CONCLUSIONS

1. Carbon monoxide asphyxiation is responsible for many otherwise inexplicable highway accidents.
2. The underlying cause of this hazard is the escape of engine exhaust gases from leaks in the exhaust system and their entrance into the car in dangerous quantities.
3. The exhaust systems of motor vehicles should be checked carefully and frequently to detect the presence of any defects from which gases may escape before reaching the exhaust pipe outlet. The immediate correction of such defects is essential to the safety of the motoring public, as well as to the driver and passengers in the defective car.
4. Exhaust pipes should be extended to the extreme rear end of the automobile, so as to provide for the unobstructed discharge and dissipation of engine exhaust gases into the atmosphere.
5. Mufflers should be constructed of heavy gauge metal, capable of withstanding ordinary wear and tear and the corrosive effect of exhaust gases. Rigid gas-tight connections should be provided between the muffler and exhaust pipes.
6. Keeping windows open while driving is not in itself insurance against carbon monoxide asphyxia.
7. There is little, if any danger of carbon monoxide asphyxiation while driving along the highway, regardless of weather or road conditions or window adjustments, provided the exhaust system is free from leaks.



## MORBIDITY

## Complete Reports for Following Diseases for Week Ending April 29, 1939

## Chickenpox

788 cases: Alameda County 3, Alameda 11, Berkeley 18, Livermore 1, Oakland 28, Piedmont 2, San Leandro 3, Chico 4, Gridley 2, Colusa County 1, Colusa 2, Contra Costa County 3, Antioch 5, Pittsburg 2, Placerville 1, Fresno County 21, Fresno 4, Sanger 1, Orland 19, Imperial County 1, Brawley 1, Imperial 1, Kern County 17, Taft 1, Los Angeles County 40, Alhambra 11, Burbank 2, Compton 9, El Segundo 1, Glendale 10, Huntington Park 5, Inglewood 1, Long Beach 3, Los Angeles 101, Pasadena 14, Redondo 1, San Fernando 1, San Gabriel 2, San Marino 9, Santa Monica 5, Sierra Madre 6, South Pasadena 2, Torrance 1, Lynwood 6, Hawthorne 1, South Gate 5, Bell 5, Gardena 1, Madre County 7, Chowchilla 4, Mill Valley 2, Ross 1, San Anselmo 1, Ukiah 4, Merced County 2, Merced 10, Monterey County 3, Orange County 4, Anaheim 4, Brea 1, Fullerton 1, Orange 1, Riverside County 2, Corona 3, Indio 1, Sacramento County 1, Sacramento 35, San Bernardino County 6, Redlands 1, San Diego County 53, Chula Vista 5, El Cajon 5, Escondido 4, La Mesa 2, National City 18, Oceanside 1, San Diego 65, San Francisco 55, San Joaquin County 11, Stockton 7, San Luis Obispo 1, Burlingame 2, Santa Barbara 4, Santa Clara County 12, Palo Alto 3, San Jose 4, Santa Cruz County 1, Redding 1, Solano County 3, Sonoma County 6, Santa Rosa 8, Tehama County 1, Red Bluff 2, Tulare County 9, Exeter 1, Lindsay 2, Visalia 1, Ventura County 1, Santa Paula 1, Ventura 1, Yolo County 8, Yuba County 2.

## Diphtheria

27 cases: Oakland 1, San Leandro 1, Contra Costa County 1, Los Angeles County 1, Arcadia 1, Glendale 1, Los Angeles 1, Pomona 1, Ukiah 6, King City 1, San Diego 2, San Francisco 1, San Luis Obispo 1, Santa Clara County 6, Santa Cruz County 1, Tulare 1.

## German Measles

29 cases: Berkeley 1, Oakland 3, Piedmont 1, Kern County 1, Kings County 1, Los Angeles County 3, Long Beach 3, Los Angeles 3, Orange County 1, Plumas County 1, Riverside 1, San Diego 3, Lompoc 1, Exeter 1, Visalia 5.

## Influenza

80 cases: Berkeley 4, Fresno County 7, Kern County 1, Los Angeles County 12, Culver City 1, El Monte 5, Glendale 2, Los Angeles 12, Santa Monica 1, Monterey Park 1, Madera County 1, San Diego County 4, San Diego 2, Santa Clara County 4, San Jose 22, Visalia 1.

## Malaria

6 cases: Kern County 2, Compton 1, Riverside 1, Stockton 1, Tulare County 1.

## Measles

2708 cases: Alameda County 32, Alameda 16, Albany 16, Berkeley 78, Hayward 1, Oakland 81, Piedmont 2, San Leandro 4, Chico 1, Contra Costa County 19, Antioch 1, Hercules 1, Martinez 7, Pinole 5, Pittsburg 6, Richmond 25, Walnut Creek 1, El Dorado County 2, Fresno County 32, Fresno 19, Glenn County 2, Imperial County 2, Kern County 22, Bakersfield 2, Delano 1, Kings County 3, Lake County 17, Los Angeles County 295, Alhambra 17, Arcadia 3, Burbank 21, Claremont 7, Compton 11, Culver City 6, El Monte 7, Glendale 40, Huntington Park 2, Inglewood 2, La Verne 1, Long Beach 97, Los Angeles 470, Manhattan 1, Monrovia 6, Montebello 3, Pasadena 28, Pomona 11, Redondo 4, San Fernando 1, San Gabriel 3, San Marino 2, Santa Monica 21, Sierra Madre 1, South Pasadena 8, Torrance 9, Lynwood 6, Hawthorne 5, South Gate 12, Monterey Park 8, Signal Hill 1, Maywood 2, Bell 3, Gardena 2, Marin County 1, Mill Valley 18, Ross 4, San Anselmo 7, San Rafael 2, Ukiah 14, Merced County 11, Gustine 18, Merced 12, Mono County 3, Monterey County 17, Salinas 3, Napa County 2, Orange County 21, Anaheim 8, Fullerton 25, Huntington Beach 8, Santa Ana 20, Seal Beach 2, La Habra 1, Laguna Beach 1, Tustin 1, Plumas County 9, Riverside County 21, Corona 13, Elsinore 1, Perris 1, Riverside 4, Indio 22, Sacramento County 1, Sacramento 107, San Benito County 1, San Bernardino County 67, Ontario 2, Redlands 1, San Bernardino 5, San Diego County 14, Chula Vista 11, La Mesa 1, San Diego 81, San Francisco 65, San Joaquin County 28, Lodi 6, Stockton 30, San Luis Obispo County 18, Paso Robles 13, San Mateo County 7, Burlingame 8, Daly City 2, Redwood City 1, San Mateo 41, Atherton 1, San Carlos 1, Menlo Park 46, Santa Barbara County 3, Santa Barbara 6, Santa Maria 1, Santa Clara County 70, Gilroy 32, Los Gatos 2, Mountain View 15, Palo Alto 16, San Jose 1, Sunnyvale 6, Shasta County 21, Redding 3, Solano County 9, Sonoma County 16, Petaluma 4, Santa Rosa 42, Stanislaus County 18, Modesto 7, Oakdale 39, Tulare County 10, Lindsay 22, Tulare 1, Visalia 6, Ventura County 1, Santa Paula 1, Yolo County 8, Davis 2, Winters 1, Woodland 3.

## Mumps

851 cases: Alameda County 13, Alameda 2, Albany 3, Berkeley 50, Livermore 1, Oakland 72, Piedmont 8, San Leandro 3, Contra Costa County 28, Antioch 8, Martinez 1, Pittsburg 1, Richmond 22, Walnut Creek 1, Fresno County 22, Fresno 6, Imperial County 1, Kern County 62, Bakersfield 4, Delano 1, Kings County 6, Lake County 1, Los Angeles County 34, Alhambra 4, Arcadia 3, Burbank 2, Culver City 1, Glendale 14, Huntington Park 1, Inglewood 1, Long Beach 8, Los Angeles 52, Monrovia 1, Montebello 1, Pasadena 19, Redondo 1, San Fernando 1, San Gabriel 1, San Marino 5, Santa Monica 6, South Pasadena 1, Whittier 1, Mill Valley 14, Ross 12, San Anselmo 4, San Rafael 2, Merced County 1, Merced 5, Monterey 2, Anaheim 1, Santa Ana 1, Placer County 8, Plumas County 3, Riverside County 2, Riverside 3, Sacramento County 21, Sacramento 30, San Bernardino County 6, Redlands 1, San

Diego County 4, Oceanside 2, San Diego 9, San Francisco 75, San Joaquin County 18, Stockton 18, San Luis Obispo County 3, Burlingame 2, Lompoc 1, Santa Clara County 35, Gilroy 3, San Jose 2, Santa Cruz County 3, Shasta County 7, Redding 5, Solano County 8, Santa Rosa 8, Stanislaus County 7, Modesto 4, Tehama County 3, Red Bluff 1, Trinity County 1, Tulare County 4, Exeter 1, Lindsay 1, Tulare 1, Visalia 19, Oxnard 1, Yolo County 3, Woodland 13.

## Pneumonia (Lobar)

64 cases: Alameda 1, Oakland 2, Walnut Creek 1, El Dorado County 1, Los Angeles County 9, Culver City 1, Glendale 1, Long Beach 1, Los Angeles 20, Pomona 1, Santa Monica 1, Whittier 1, Salinas 1, Santa Ana 1, Riverside 1, Sacramento County 1, Sacramento 3, San Francisco 10, San Luis Obispo County 1, San Luis Obispo 1, Mountain View 1, San Jose 1, Yuba County 3.

## Scarlet Fever

176 cases: Alameda 1, Berkeley 2, Oakland 4, Chico 1, Contra Costa County 2, Martinez 3, El Dorado County 1, Fresno County 2, Fresno 2, Kern County 3, Delano 5, Los Angeles County 18, Alhambra 1, Compton 3, El Segundo 2, Glendale 1, Hermosa 1, Huntington Park 1, Long Beach 1, Los Angeles 40, Pasadena 1, Redondo 1, San Gabriel 1, Santa Monica 2, Sierra Madre 2, Torrance 1, Lynwood 2, Monterey Park 2, Bell 1, Madera County 1, San Rafael 1, Merced County 1, Monterey County 1, Orange County 4, Newport Beach 1, Santa Ana 1, Laguna Beach 1, Corona 1, Indio 2, Sacramento County 1, Sacramento 4, San Bernardino County 2, Ontario 1, San Diego County 1, San Diego 7, San Francisco 12, San Joaquin County 2, Stockton 1, San Luis Obispo County 1, Arroyo Grande 1, Burlingame 3, Santa Barbara County 1, Santa Clara County 1, San Jose 2, Solano County 1, Modesto 2, Tehama County 1, Red Bluff 1, Tulare County 2, Exeter 3, Lindsay 1, Tulare 1, Ojai 1, Yolo County 1, Sonoma County 1.

## Smallpox

22 cases: Fresno County 4, Brawley 1, El Centro 4, Kings County 1, Riverside County 1, Corona 1, Hollister 2, San Bernardino County 1, National City 2, Tulare County 2, Porterville 1, California 2.\*

## Typhoid Fever

5 cases: Oakland 1, Brawley 1, Chula Vista 1, San Joaquin County 1, Stanislaus County 1.

## Whooping Cough

227 cases: Berkeley 4, Butte County 1, Concord 1, Fresno County 2, Imperial County 1, Kern County 6, Bakersfield 5, Los Angeles County 22, Alhambra 7, Compton 1, El Segundo 1, Glendale 5, Huntington Park 2, Long Beach 19, Los Angeles 30, Pasadena 11, Redondo 1, San Fernando 11, Gardena 2, San Anselmo 1, Mariposa County 1, Anaheim 5, Fullerton 4, Santa Ana 2, Riverside County 3, San Bernardino County 1, San Diego County 6, Oceanside 1, San Diego 29, San Francisco 9, San Joaquin County 8, San Luis Obispo County 1, Daly City 2, Santa Barbara County 1, Sunnyvale 1, Sonoma County 1, Santa Rosa 2, Stanislaus County 2, Lindsay 1, Ventura County 7, Oxnard 6, Davis 1.

## Meningitis (Epidemic)

One case: Redwood City.

## Dysentery (Amoebic)

4 cases: Inglewood 1, Los Angeles 1, San Diego 1, Oakdale 1.

## Dysentery (Bacillary)

8 cases: Los Angeles.

## Poliomyelitis

4 cases: Kern County 2, Bakersfield 1, La Habra 1.

## Tetanus

One case: Madera County.

## Trachoma

8 cases: Indio 7, Burlingame 1.

## Trichinosis

One case: Oakland.

## Food Poisoning

14 cases: Los Angeles 9, Pasadena 4, South Gate 1.

## Undulant Fever

9 cases: Los Angeles County 3, Compton 1, Orange County 1, Perris 2, Oakdale 1, Marysville 1.

## Tularemia

One case: Brawley.

## Coccidioidal Granuloma

2 cases: Kern County 1, San Francisco 1.

## Septic Sore Throat

One case: Monterey County.

## Rabies (Animal)

23 cases: Calxico 1, Los Angeles County 4, Alhambra 1, Compton 1, Culver City 1, Los Angeles 10, South Pasadena 1, Monterey County 1, Santa Clara County 1, San Jose 1, Santa Paula 1.

\* Cases charged to "California" represent patients ill before entering the state or those who contracted their illness traveling about the state throughout the incubation period of the disease. These cases are not chargeable to any one locality.